

CFD Tools in Stirling Engine Virtual Design

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Abstract

A successful realization of Stirling engines is conditioned by its correct conceptual design and optimal constructional and technological mode of all parts. Initial information should provide computation of real cycles of the engines. Present calculation models of thermodynamic cycles of the external heat supply engines, e.g. Stirling or Ericsson engine, arise from ideal theoretical cycles which are known from basics of thermodynamics that are, for this purpose, modified by various methods [1, 2, 3, 4, 5]. High-level CFD (Computational Fluid Dynamics) models, arising from the description of real processes which run in external heat supply engine are used for virtual prototype of Stirling engine.

1. Introduction

Requirements of computational modeling of different physical phenomena rise in the present time. Dynamics of Stirling engine parts and dynamics of fluid processes in the respective characteristic areas (or volumes) of external heat supply engines are specific which is given by the fact that the course of observed values (force, temperature, pressure, heat transfer, etc.) is periodical.

Modern computational models deliver relative accurate results but only if correct inputs are included. This represents a fundamental drawback of modern computational methods. The correct inputs can be greatly obtained from measurements and therefore the measurements are continuously a fundamental part of the Stirling engine development.

2. Computational Models of Stirling Engine

The development of a computational models starts with CAD model of the Stirling engine (Figure 1). Stirling engine geometry is set to an initial cranktrain position. A volume of a working medium is created by a subtraction of a Stirling engine CAD model from a properly chosen volume (Figure 1). A geometrical symmetry of an inner working medium volume can be used. Consequently a high quality hexa mesh is generated.

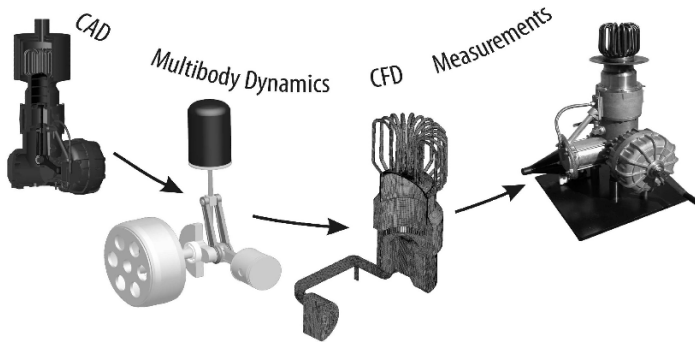


Fig. 1. Stirling engine development cycle using CAD, MBS and CFD tools and measurements

2.1. Multibody Dynamics

Multi-body systems (MBS) can be applied as effective tools for solving Stirling engine dynamics. Multi-body systems enable solving different dynamic issues of complex systems combining rigid and flexible bodies. In the case of Stirling engine mechanisms, they can be used to find the optimum alternative for balancing the driving mechanism [6]. When the mechanism moves, inertial forces of different moving parts take effect. These cause vibrations and must be "captured" by means of the machine seating. A virtual mechanism prototype has been created in the multi-body system and the Stirling engine driving mechanism has been optimised to produce low vibrations.

2.2. CFD

The application of known computational models derived for stationary states is therefore not possible. In the recent years computational fluid

dynamics (CFD) has been enormously developed and therefore is applied to the development of Stirling engine thermodynamic cycle.

The aim of the project is to develop calculation models of real thermodynamic cycles of external heat supply engines, which will enable us to calculate the thermodynamic cycle parameters necessary for structural design of engines with higher order accuracy precision. In the second phase, a virtual prototype of external heat supply engine will be made as a complex calculation model. This complex calculation model enables to find optimal parameters of the engine, for example, design and materials of a regenerator, proper design of a combustor modulus or Stirling engine working medium.

3 Stirling Engine Thermodynamic Cycle Results

The computational model of a Stirling engine thermodynamic cycle can be used in many ways. Generally, the first question can be what sort of a working medium should be used. The CFD model can give relatively precise answer.

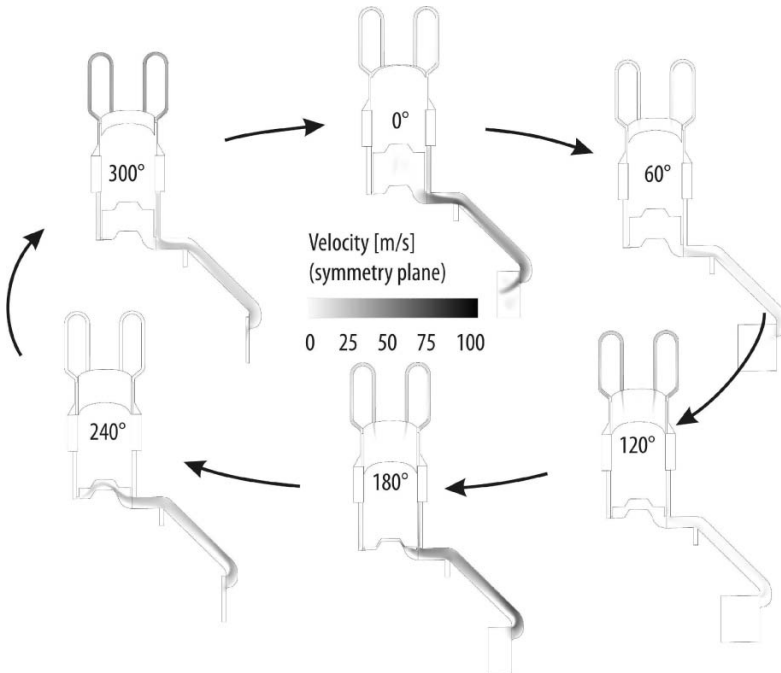


Fig. 2. Computed velocity distributions on symmetry plane vs. crank angle (air)

A fundamental request for a Stirling engine construction is a fluent flow without any pressure losses. Figure 2 presents computed velocity distribution on a symmetry plane of the engine vs. a crank angle if air is used as a working medium. Initial static pressure in an engine volume is set to value of 1 MPa.

The complex computational model enables to solve the α -type Stirling engine combustor modulus in detail. A heat source distribution is optimized to uniform heating of the combustor modulus. Various types of design and materials of a regenerator are also discussed to ensure maximal thermal efficiency of the Stirling engine.

A computed temperature distribution on a symmetry plane of the engine vs. a crank angle is shown in Figure 3.

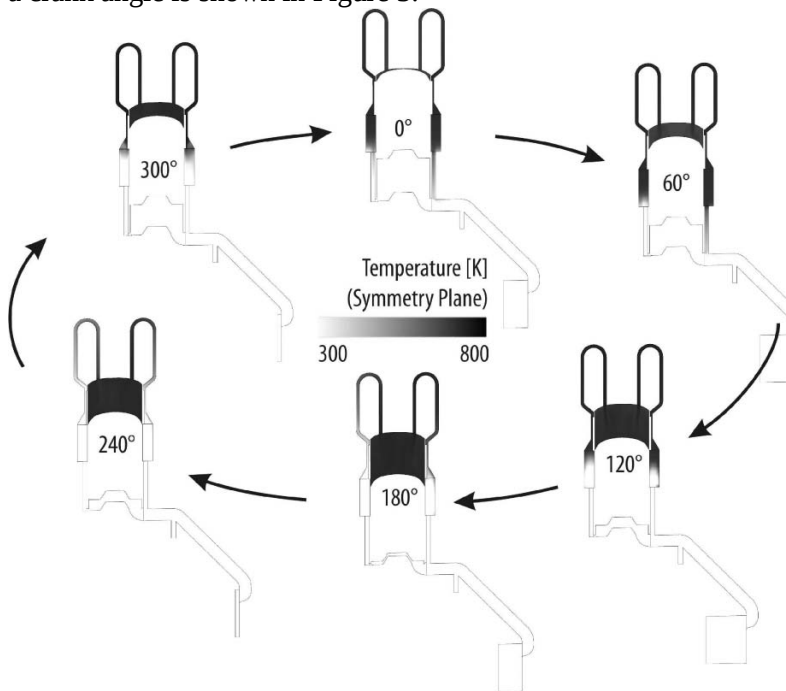


Fig. 3. Computed temperature distributions on symmetry plane vs. crank angle (air)

4. Conclusion

Computational models of thermodynamic cycles of the Stirling engine are being created as higher-level computational models based on CFD models

of physical processes occurring in real units, using only the minimum simplifying assumptions. New computational models will be created after the necessary number of technical experiments is made. They will speed up the development of Stirling engines with better technical and economic parameters.

Acknowledgement

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